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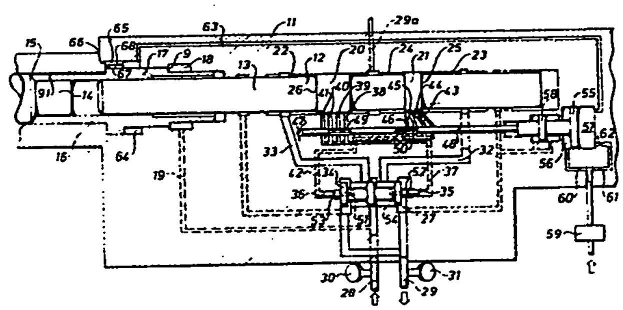
(54) **Method of controlling an impact motor and an impact motor.**

(57) In a rock drill, the feed force is transmitted from the housing 11 of the rock drill to the drill stem or drill stem adapter 14 via a damping piston 17. The damping piston 17 rebounces by the reflected compressive shock waves and the rebounce is sensed and used to control a control pin 48 which adjusts the stroke length of the hammer piston 13 so that the reflected shock wave energy is minimized.



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Method of controlling an impact motor and an impact motor

This invention relates to a method of controlling an impact motor that comprises a reciprocating hammer piston that, when impacting upon an anvil, converts its kinetic energy to shock wave energy that propagates through an elongate tool, for example a tool in the form of a drill stem or chisel.

The invention relates also to an impact motor of the kind described above which has an adjusting device for adjusting the impact velocity of the hammer piston.

In rock drilling, it is known that an increased impact energy per blow results in an increased penetration rate up to a certain level. If the impact energy is increased over this level, the penetration rate increases very little whereas the drill bit wear increases considerably.

It is also known in the art that a worn drill bit requires a higher impact energy than a new or newly sharpened drill bit in order to give the same penetration rate.

Usually in a rock drill, the hammer piston impacts at a constant impact energy per blow independently of the gradually varying condition of the drill bit and of changing rock properties.

It is an object of the invention to permit for control of the impact motor in order to utilize the impact energy more effectively. The impact motor can then for example be the impact motor of a rock drill or a jack hammer. This object is achieved by the features given in the characterizing parts of the claims.

The kinetic energy of the hammer piston propagates in the form of a compression wave through the tool which can be a rock drill stem. The major portion of the part of the shock wave energy that is not utilized for the rock destruction is reflected as shock wave energy either in the form of compression waves or tensile waves. This energy

may also be reflected partly as compression waves and partly as tensile waves.

According to the invention, the reflected shock waves are sensed and the impact velocity is adjusted in response thereto so that the reflected shock wave energy will be small. Advantageously, the movement coupled to the reflected shock waves is sensed and the movement is minimized. It is particularly advantageous to sense the rebounce of an elastically yieldable element that is arranged to transmit a feed force to the tool and to adapt the impact velocity of the hammer piston so that the rebounce of the yieldable element will be samll but does not disappear. There should be a slight rebounce since it is the compression wave energy only that makes the element rebounce. The tensile wave energy does not affect the rebounce and if there is no rebounce at all the impact velocity may be accurate but it may also be too high.

The invention will be described with reference to the accompanying drawings.

Fig 1 is a longitudinal view of an impact motor according to the invention, e.g. the impact motor of a rock drill.

Fig 2 is a longitudinal view of an impact motor according to the invention, e.g. the impact motor of a rock drill.

Fig 3 is a longitudinal view of an impact motor according to the invention, e.g. the impact motor of a rock drill.

Fig 4 is a longitudinal view of the front end of a rock drill which can be the front end of any one of the impact motors of Fig 1, Fig 2, or Fig 3 when they are adapted as rock drills.

The impact device shown in Fig 1 is a hydraulic rock drill, a hydraulic jack hammer or the like. It comprises a housing 11 forming a cylinder 12 in which a hammer piston 13 is reciprocable to impact upon an anvil element 14, for example a chisel, a rock drill stem or

an adapter for a rock drill stem. A shoulder 15 on the anvil element takes support on a sleeve 16 on a damping piston 17 for damping the reflected compressive shock waves. The damping piston 17 is forced forwardly into its foremost position as shown by the hydraulic pressure in a cylinder chamber 18 that is constantly pressurized through a passage 19. The pressure acts on an annular piston surface 9 of the damping piston. The hammer piston 13 has two lands 20, 21 so that a front cylinder chamber 22, a rear cylinder chamber 23 and an intermediate cylinder chamber 24 are formed between the piston 13 and the cylinder 12. The piston 13 is driven forwardly by the pressure acting on its surface 25 and driven rearwardly by the pressure acting on its surface 26. A valve 27 is connected to an inlet 28 coupled to a source of high pressure hydraulic fluid and to an outlet 29 coupled to tank. Accumulators 30, 31 are coupled to the inlet 28 and the outlet 29. The intermediate cylinder chamber 24 is constantly connected to the outlet 29 by means of a passage 29a. The valve 27 is coupled to the rear cylinder chamber 23 by means of a supply passage 32 and to the front cylinder chamber 22 by means of a supply passage 33. The valve 27 has a valving spool 34 which in its illustrated position connects the rear cylinder chamber 23 to pressure and the front cylinder chamber 22 to tank. The spool 34 has cylindrical end portions 35, 36, the end faces of which have piston surfaces that are subject to the pressure in control passages 37, 42 that each are branched into four branches so that they each have four ports 38, 39, 40, 41 and 43, 44, 45, 46 respectively into the cylinder 12. A cylindrical bore 47 intersects all eight branches and a cylindrical pin 48 is slidable with a tight fit in the bore 47. This pin 48 has two recesses 49, 50. Integral with the pin 48 there is a control piston 55 that divides a cylinder into two cylinder chambers 56, 57 and a dash pot piston 58.

Compressed air is supplied through a pressure regulator 59 to the two cylinder chambers 56, 57 via two passages 60, 61. The passage 61 contains a restriction 62.

A passage 63 leads from the cylinder chamber 57 to a cylinder chamber 64 formed between the housing 11 and a land 65 on the damping

piston 17. The front end face 66 of the land abuts against a shoulder 67 in the housing 11 to define the impact position of the anvil element 14. One or more passages 68 lead axially through the land 65 and they are closed when the damping piston 17 is forced forwardly into its normal positon as shown in Fig 1 but they are vented through a passage 69 to the atmosphere when the damping piston 17 is off the shoulder 67.

The operation of the impact device of Fig 1 will now be described. The hammer piston 13 is shown in Fig 1 moving forwardly in its work stroke (to the left in Fig 1), and the valve spool 34 is then in its illustrated position. When the port 45 of the control passage 42 is opened to the rear cylinder chamber 23, the control passage 42 will convey pressure to the control piston 36 so that the valve spool 34 is moved to the right in Fig 1. The valve spool 34 should prefereably finish its movement at the very moment the hammer piston 13 impacts upon the anvil 14. Thus, the pressure existing from the moment of impact in the front cylinder chamber 22 moves the hammer piston 13 rearwardly until the branch 40 of the control passage 37 is opended to the front pressure chamber 22. Then, the control passage 37 conveys pressure to the control piston 35 which moves the valve spool 34 back to its illustrated position so that the rear cylinder chamber 23 is again pressurized. The pressure in the rear cylinder chamber 23 retards the hammer piston 13 and accelerates it forwardly again so that the hammer piston 13 performs another work stroke.

The valve spool 34 has annular surfaces 52, 53 and internal passages 51, 54 which hold the valve spool in position during the periods when the control pistons 35, 36 do not positively hold the piston. The annular surfaces 52, 53 are smaller than the end faces of the pistons 35, 36.

When the pin 48 is in its illustrated position, the port 40 of the control passage 37 and the port 45 of the control passage 42 are the ports that make the valve spool shift position. The other ports are inactivated. In other positions of the pin 48 one pair of the three pairs of ports 38, 43; 39, 44 and 41, 46 respectively is selected to cooperate to control the valve.

The first one of the ports 38-41 that is opened to the front cylinder chamber 22 during the return stroke of the hammer piston initiates the valve spool 34 to shift position. Thus, by adjusting the axial position of the pin, the operator pre-selects the stroke length of the hammer piston. The axial distances between the ports 43-46 are smaller than the corresponding distances between the ports 38-41. The axial positions of the ports 43-46 in the cylinder are such that for each stroke length the selected one of the ports 43-46 is uncovered a distance before the impact postion of the hammer piston, and the distance is such that the valve spool has just moved to its position for pressurizing the front pressure chamber when the hammer piston 13 impacts the anvil 14. The distances between the ports 43-46 are such that the selected port is uncovered the same period of time before impact occurs independently of which one of the four ports is selected.

When there are no reflected compressive shock waves, the damping piston 17 will not rebounce and the passage 63 will be constantly blocked. Thus, there will be a pressure balance on the piston 55. The differential area of the piston 55 will move the piston to the left in Fig 1 and the stroke length of the hammer piston will accordingly decrease until the damping piston 17 starts to rebounce. The periodic rebounce will cause air to leak through the passage 63 so that the pressure in the chamber 57 decreases and the piston will stop moving to the left in Fig 1. The piston should be so balanced that it takes up a position in which the damping piston 17 rebounces only a little, which means that a slight amount of energy reflects as compression waves. The balance of the piston is defined by its differential area, the restriction 62, the supplied air pressure, and of course the damping piston 17. The dash-pot piston 58 slows down the movement of the damping piston 17, and makes the control more stable.

When the drill bit is new or newly regrinded, it needs less shock wave energy and the stroke length is automatically reduced so that the drill bit will not wear down unnecessarily fast. Then, the stroke length increases as the drill bit becomes worn. The stroke length is also automatically adjusted to varying rock properties and to the length of the drill stem when the drill stem is made up of extention

rods.

In Fig 2, an alternative system for controlling the pin 48 is shown. A plunger piston 71 is fixed with the pin 48 and a passage 72 with a check valve 73 leads directly between the cylinder chamber 18 of the damping piston 17 and the cylinder chamber 74 of the plunger piston 71. The check valve 73 is by-passed by a passage 75 with a restriction 76. An annular land 77 between the pin 48 and the plunger piston 71 divides a wider cylinder into two cylinder chambers 78, 79. The cylinder chamber 78 is continuously drained through a passage 80 and the cylinder chamber 79 is continuously pressurized through a passage 81. In order to make the system insensitive to the pressure level of the hydraulic system, the annular area in the cylinder chamber 79 should equal the plunger area. A spring 82 is arranged to bias the pin 48 to the left in Fig 2.

During drilling, the rebounces of the damping piston 17 result in pressure peaks in the chamber 18. The check valve 73 which is closed at the normal pressure level, opens for each peak and supplies a small amount of fluid to the plunger cylinder 74, and the plunger piston 71 will move the pin 48 to the right in the figure against the action of the spring so that the stroke length of the hammer piston 13 increases as described with reference to Fig 1. When the rebounces decrease, the spring 82 will force the plunger 71 and the pin 48 to the left in Fig 2 until the rebounces again tend to increase. Thus, the pin 48 will be controlled in response to the compressive shock waves as in the embodiment of Fig 1.

In the impact motors of Figs 1 and 2, the damping piston 17 is biassed forwardly into a defined normal position into which it returns or nearly returns before each impact provided that the feed force applied to the housing 11 is smaller than the force applied to the piston surface 9 of the damping piston.

In Fig 3, an hydraulic impact motor is shown which has a valve 27 and a valve control system that accepts variation within certain limits of the position of the impact surface of the anvil at the instant of

impact. Therefore, the damping piston 17 can be floating as shown in Fig 3. The pin 48 controls the valve control passage 37 only, it does not control the valve control passage 42. The pin 48 is controlled by compressed air of a controlled pressure in the same way as shown in Fig 1 but the venting of the passage 63 is different. The chamber 18 is supplied with compressed air of a controlled pressure from a supply passage 85 through a check valve 86 so that the air in the chamber 18 forms an air spring. A counter piston 87 has an annular piston surface 88 in a cylinder chamber 87 which is, in use, constantly pressurized by being connected to the supply passage 85. The piston surface 88 of the counter piston 87 must be substantially smaller than the piston surface 9 of the damping piston 17.

When drilling is to be started, compressed air is first supplied to the supply passages 60, 61, 88 so that the damping piston 17 moves to the left in Fig 3. When the feed force is supplied to the housing 11 and the impact motor is started, the housing 11 moves forwardly i.e. the damping piston 17 moves inwardly in the housing 11 so that the air in the chamber 18 is compressed until the resultant force of the air spring force on the surface 9 and the force on the surface 88 balances the resultant force of the feed force and the internal recoil forces.

When the damping piston rebounces, the counter piston 87 follows but since the acceleration of the rebounce is very high, there will temporary be a gap 90 between the damping piston 17 and counter piston 87. This periodical gap provides a leak passage through which the passage 63 is vented to the atmosphere via a clearance 91 between the anvil 14 and the counter piston 87. This venting of the passage 63 controls the position of the pin 48 in the same way as described with reference to Fig 1.

In the embodiments described above, the movement related to the reflected compressive shock waves only is sensed. Neither the primary compressive shock waves nor the reflected tensile shock waves will induce rebounces of the damping piston 17, which makes the system very simple.

As an alternative, the movements of the drill stem can be sensed, for example by means of light emitter, a bundle of optic fibres and a photocell. The electric signal from the photocell can then be analyzed and processed to give a control signal for controlling a control pin 48 of the kind shown in the Figures or any other kind of means for adjusting the impact velocity of the hammer piston. Then, it is advantageous to compare the movements related to the reflected shock wave with the primary shock wave and to adjust the impact velocity in response to the quotient of the lengths of the movements.

If the impact device shown in Figs 1, 2, or 3 is a rock drill, its front end can be as shown in Fig 4. Then, the shoulder 15 of the anvil element 14 is the rear end surface 15 of a non-circular widened portion 98 of a drill stem adapter 14. The portion 98 engages with a chuck bushing 92 with an insert bushing 93 so that it rotates conjointly with the chuck bushing. The chuck bushing 92 is rotated by means of a non-illustrated rotation motor through a drive shaft 95 and a gearing 94.

Although, in the Figures, only four ports 38-41 with four respective passages that intersect the bore 47 and only four ports 43-46 with four respective passages that intersect the bore 47 are shown, it is advantageous and desirable that the discrete ports and their passages axially overlap one another in order to make the control substantially stepless. For this purpose the ports and the respective passages can for example be arranged in two or three axial rows so that they axially overlap one another but still remain discrete.

Claims:

1. Method of controlling an impact motor that comprises a reciprocating hammer piston (13) that, when impacting upon an anvil (14), converts its kinetic energy to shock wave energy that propagates through an elongate tool (14), for example a tool in the form of a drill stem or chisel, characterized by the steps of sensing the reflected shock waves and adjusting the impact velocity of the hammer piston (13) in response to the sensed reflected shock waves such that the reflected shock wave energy is minimized.

2. Method according to claim 1, characterized in that the stroke length of the hammer piston (13) is adjusted in order to adjust the impact velocity of the hammer piston.

3. Method according to claim 1 or 2, characterized in that the impact velocity of the hammer piston (13) is so adjusted as to make the reflected shock wave energy small and substantially in the form of compressive wave energy.

4. Method according to any one of the preceding claims, characterized in that the movement coupled to the reflected shock waves is sensed.

5. Method according to claim 4, characterized in that the movement coupled to the reflected shock waves and the movement coupled to the primary shock waves are sensed and the impact velocity is adjusted in response to the quotient of the lengths of said movements.

6. Impact motor comprising a reciprocating hammer piston (13) that is arranged to impact upon an anvil (14) so as to convert its kinetic energy to shock wave energy that will propagate through an elongate tool (14) for example a tool in the form of a drill stem or chisel, and an adjusting device (48) for adjusting the impact velocity of the hammer piston, characterized by means (55, 71) for sensing the movement coupled to the reflected shock waves

and controlling said adjusting device (48) in response to the amount of reflected shock waves in order to minimize the reflected shock wave energy.

7. Impact motor according to claim 6 wherein an elastically yieldable element (17) is arranged to transmit a feed force to the tool, c h a r a c t e r i z e d i n that said sensing means (55) is arranged to sense the rebounce of said yieldable element (17) and to control said adjusting device (48) such that the rebounce of the yieldable element (17) will be small but existing.

Fig. 1

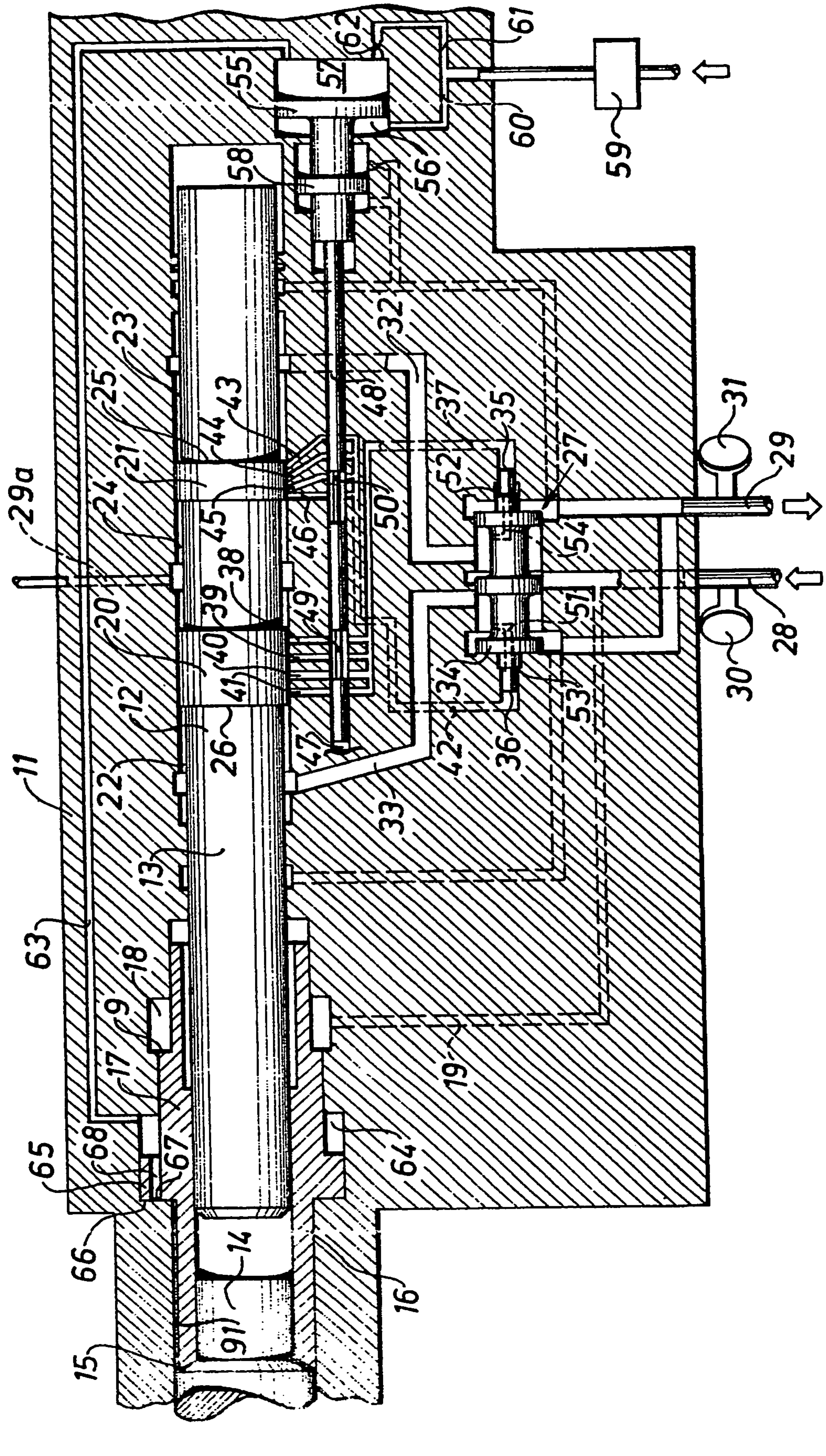

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Fig. 2

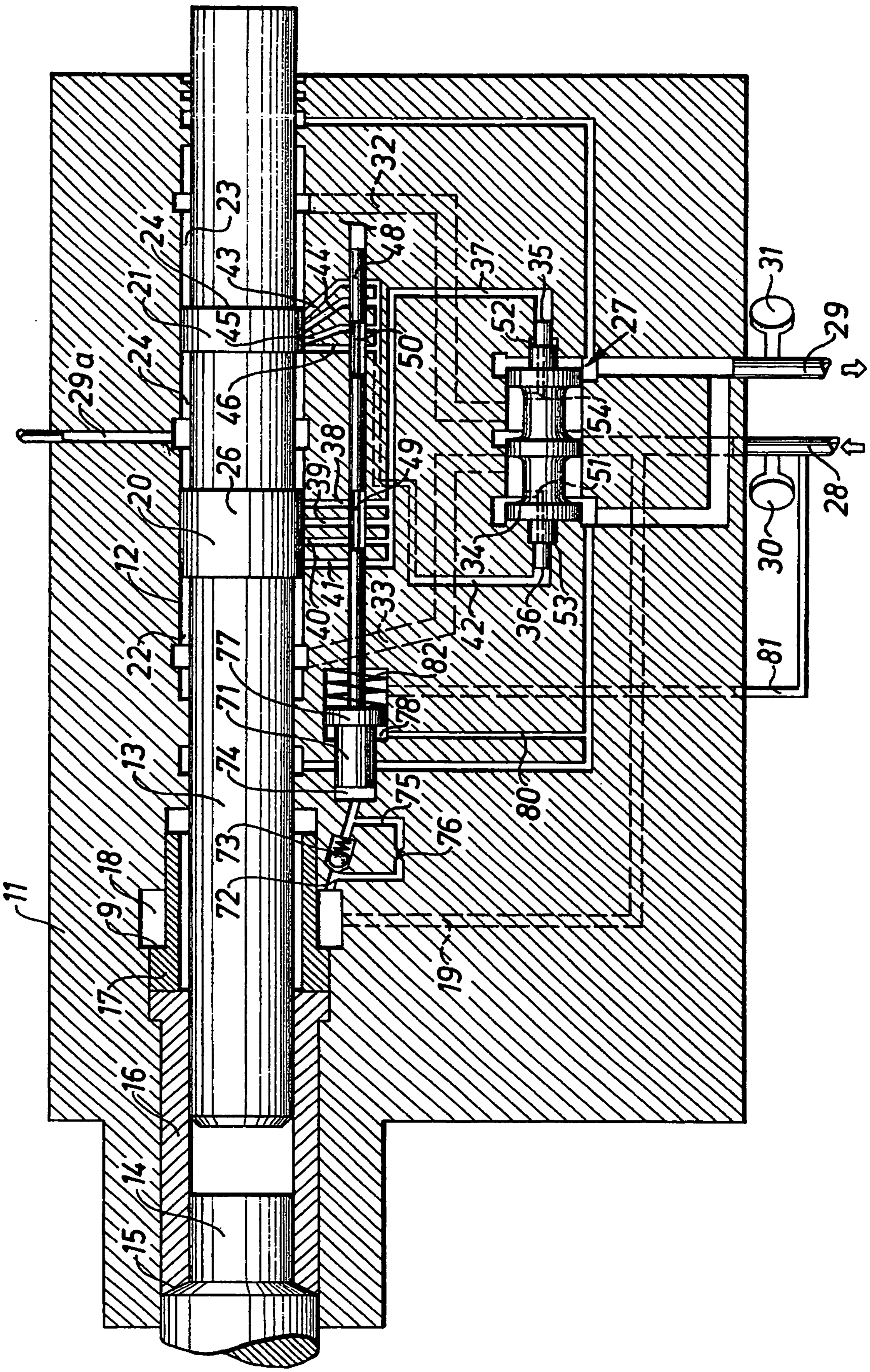

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Fig. 3

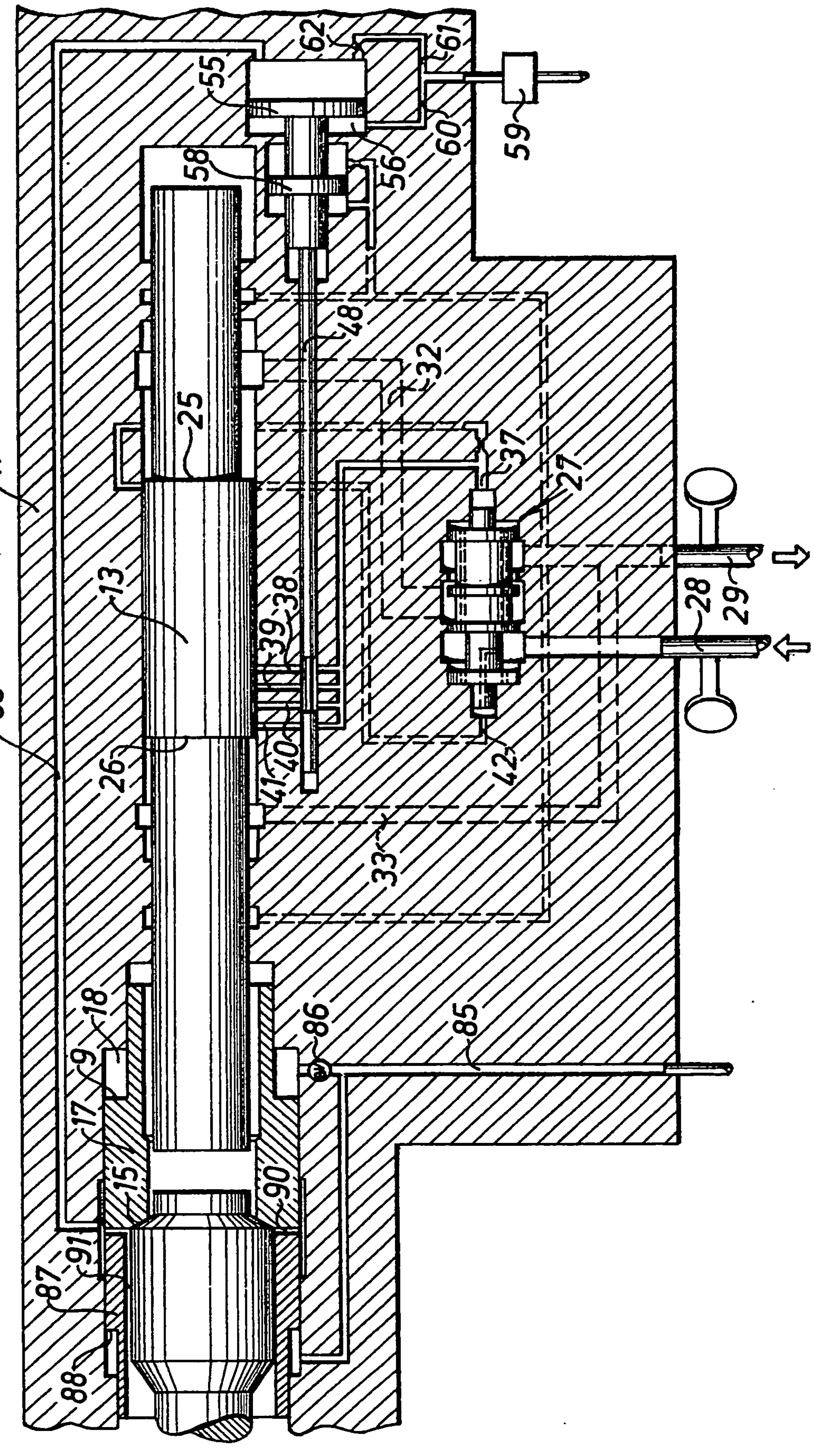
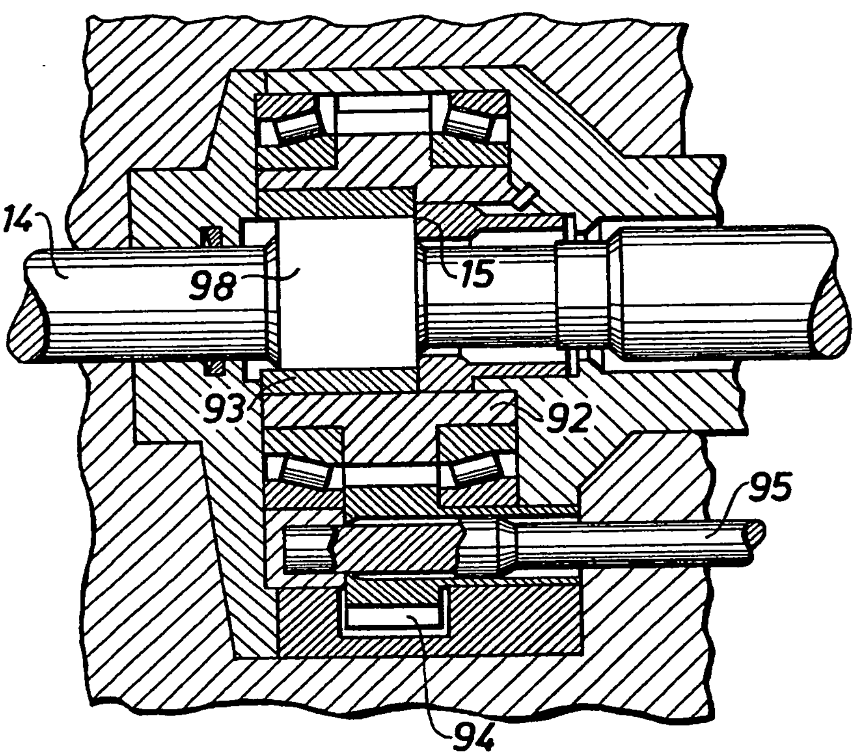


Fig. 4



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